PRECISION ANTENNA REFLECTOR STRUCTURES

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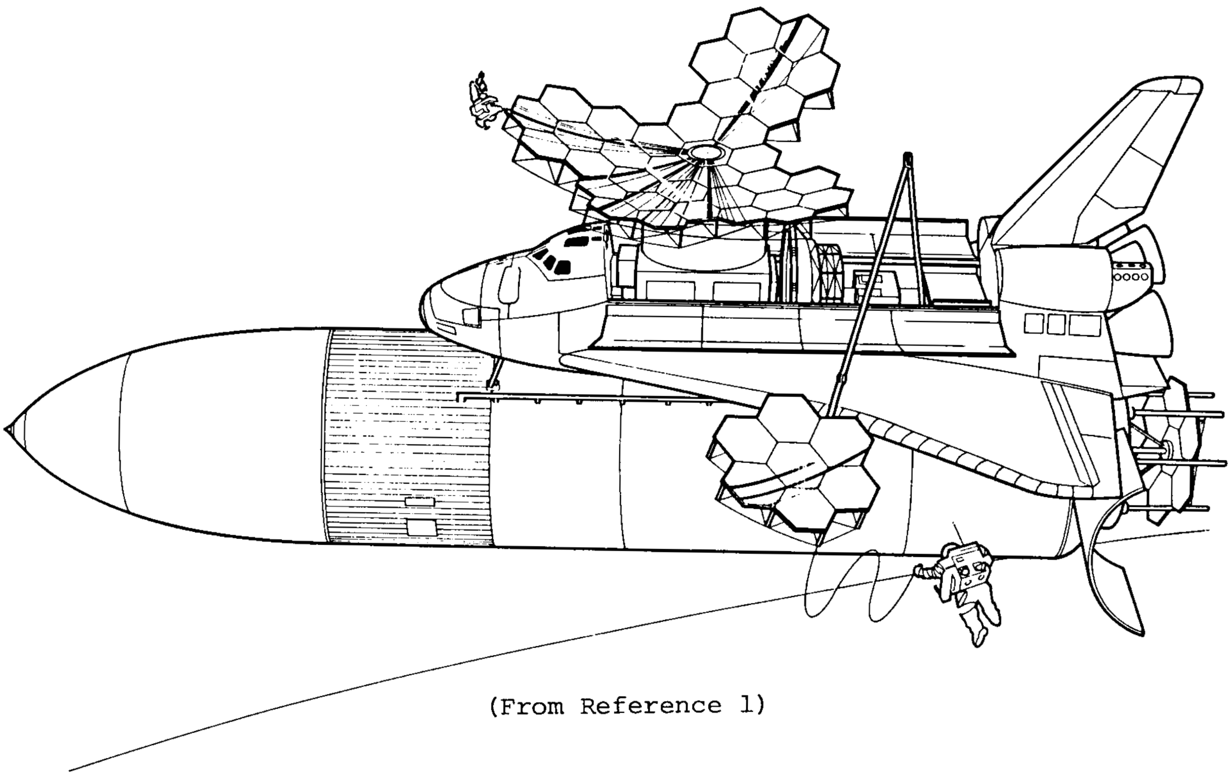
ASSEMBLY OF THE LARGE PRECISE REFLECTOR INFRARED TELESCOPE

The advancing capabilities of the Shuttle and systems designed for use with the Shuttle should have a beneficial impact on the way in which large space structures are established in space. In particular, the probable availability of a large-volume launch compartment built on the aft end of the main propellant tank could allow the preconstruction of large modules which can be assembled in space in order to create the desired aperture. This so-called Aft Cargo Carrier has a large enough diameter to allow a large aperture to be assembled from a small enough number of separate modules to make the assembly practical. The assembly approach is illustrated in Figure 1, which is taken from Reference 1.



(From Reference 1)

Figure 1

GENERAL SCIENTIFIC REQUIREMENTS

An example future mission is that of space-based astronomy at infrared and submillimeter wavelengths. Previous studies (see Reference 2, for example) indicate that a telescope 20 to 30 m in diameter is a highly desirable instrument. This telescope is often called the Large Deployable Reflector (LDR), but is herein called the Large Precise Reflector (LPR). The general telescope requirements were developed in a workshop (ref. 2) held in June 1982 and are included in Table 1.

DIAMETER	$\gtrsim$20 m
SHORTEST WAVELENGTH OF DIFFRACTION-LIMITED PERFORMANCE (λ_c)	30-50 μm
LIGHT BUCKET BLUR CIRCLE	$\lesssim$2 ARCSEC AT 1-4 μm
TEMPERATURE AND EMISSIVITY	PRIMARY $\lesssim$200 K, ε = 0.01 AT λ = 1 mm, ε = 0.05 FOR $\lambda \lesssim$1 mm
CHOPPING	2 Hz, 1 ARCMIN (REACTIONLESS)
SIDELOBES	LOW NEAR SIDELOBES
SCAN	1° BY 1° - LINEAR SCAN AT 1°/MIN
SLEW	$\gtrsim$50°/MIN
FIELD OF VIEW	$\gtrsim$3 ARCMIN
ABSOLUTE POINTING, JITTER	0.05 ARCSEC, 0.02 ARCSEC

Table 1

THE AFT CARGO CARRIER

The Aft Cargo Carrier (ACC), shown in Figure 2, is a structural enclosure that attaches to the aft end of the STS external tank. (See Reference 3 for a full description.) It provides additional cargo volume and will accommodate payloads which are incompatible with the 4.6-m diameter of the orbiter bay. The ACC can handle circular payloads up to 7.6 m in diameter.

The external tank, the ACC skirt, and the payload support structure are carried into orbit. After the payload is removed, the remaining structure is then deorbited and reenters the atmosphere for safe ocean disposal.

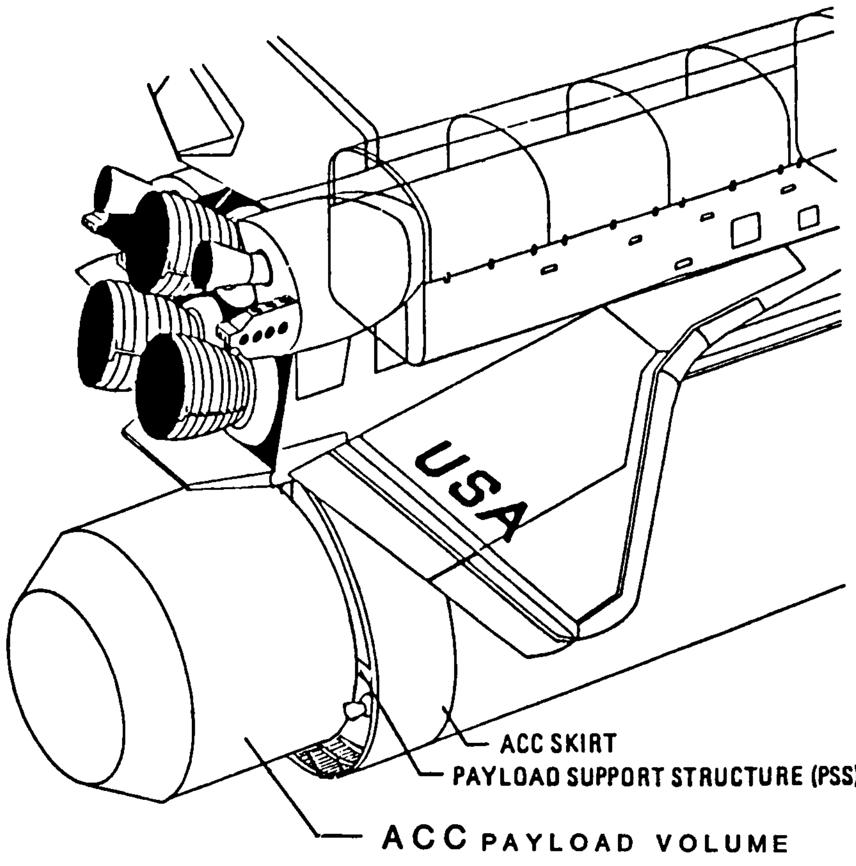


Figure 2

LARGE PRECISION REFLECTOR STRUCTURE

The most likely structural configuration for the LPR will include a segmented primary reflector composed of highly precise and polished panels which are mounted to a very stable support truss by means of adjustable actuators. One version is shown in Figure 3. A feedback control system will be used to command the actuators to adjust the positions of the segments.

The analyses of Reference 4 deal with a tetrahedral truss structure with surface struts of length L and a truss depth of H. The numerical results obtained for the 20-m aperture reflector and values of L and H of 2 m showed that hollow struts 2 cm in diameter composed of graphite/epoxy were stiff enough to resist the operational accelerations without allowing deleterious deflections. For the present study, the same tetrahedral-truss geometry is used with appropriate values chosen for L and H. The formulas derived in Reference 4 can therefore be used to predict the structural characteristics of the new concepts.

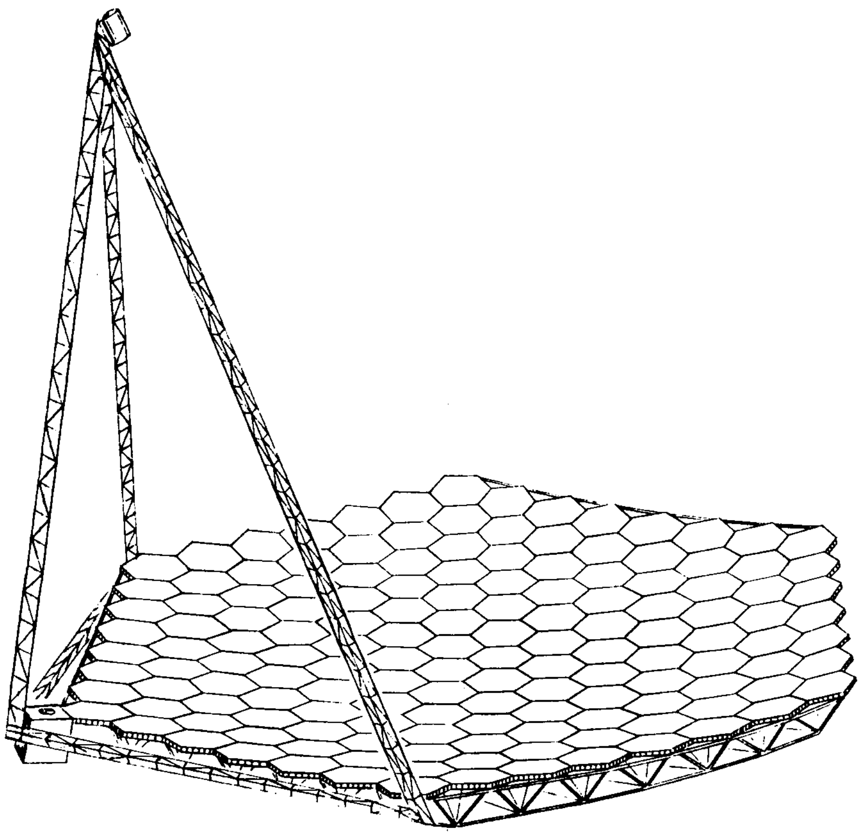


Figure 3

PACKAGING OPTIONS

A study was performed of the areal packaging efficiency of various geometries of panels. Results were obtained for logical arrangements of hexagonal and square panels. Also included was the possibility of using partial panels to fill out the notches at the boundary. In addition, geometrical arrangements with petals surrounding a central polygon might be useful. Some examples are shown in Figure 4.

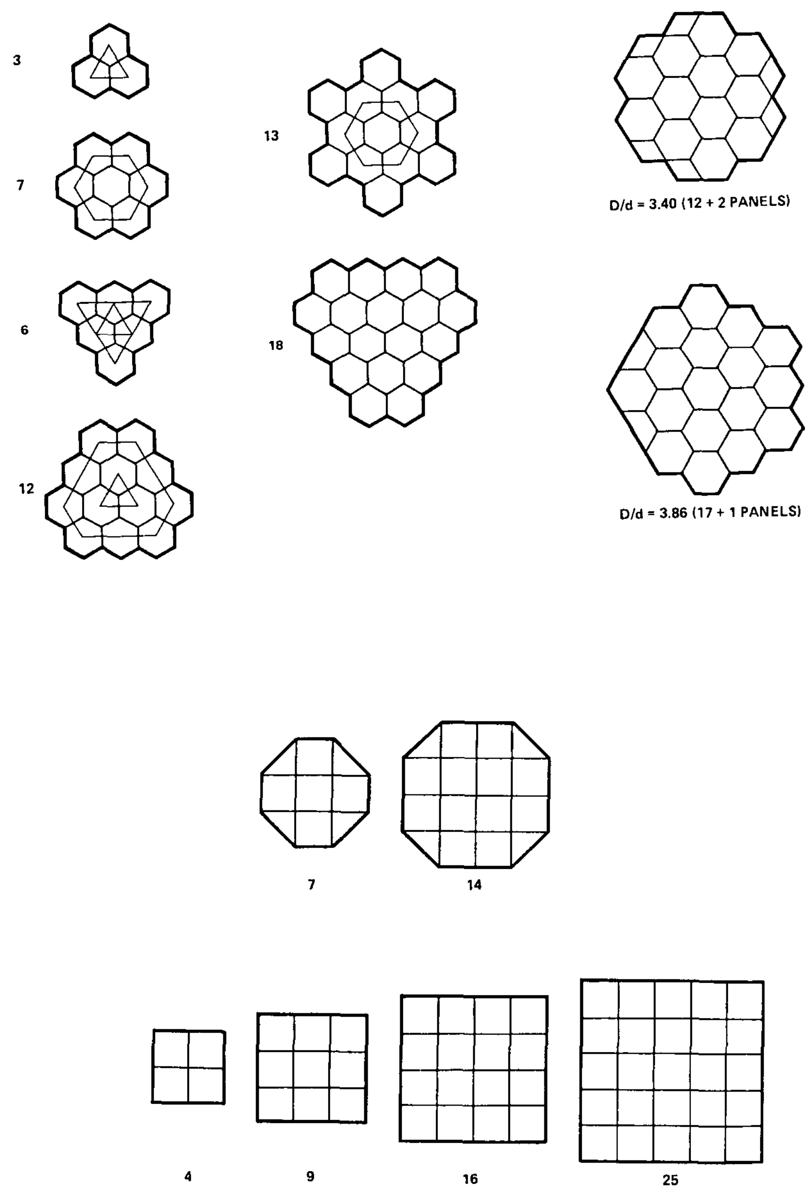


Figure 4

VARIATION OF THE RATIO BETWEEN EFFECTIVE DIAMETER AND MODULE SIZE FOR VARIOUS PANEL GEOMETRIES

A measure of efficiency is the number of panels, each of which is stowable in a diameter d to produce an assembled aperture of area equal to that of a circle of diameter D. The results are summarized in Figure 5 in which D/d is plotted against the number of panels in the packaged stack. Shown on the plot are horizontal lines at D/d = 2.53 and 3.80 which are the necessary values for an aperture of 20 m and 30 m if the package diameter is 7.9 m. Also shown is a horizontal line pertaining to the achievement of a 20-m aperture with panels stowed in the Shuttle cargo bay d = 4.5 m. The open symbols represent cases in which the number of separate pieces is equal to the number of panels in the stack. In those cases where partial panels are used to round out the boundary, the number of pieces exceeds the number of panels and is indicated by the solid symbols.

In general, the hexagonal panel gives superior results. Square panels have no advantages. The petaled configurations could be interesting, particularly the seven-sided one, which is a candidate for meeting the 20-m requirement. The packaged depth is the same as that for the hexagonal panels, but the number of pieces (eight) is less than that for the rounded hexagonal case (13). In a similar way, the folded-petal configuration is attractive for the 30-m objective. This can be met with 18 or 19 hexagonal panels. A possible competitor with smoother outer edges would be the 11-sided petaled arrangement.

It should be noted that the serrated hexagon arrangement shown in Figure 1 is equivalent in efficiency to the hexagonal panel. This arrangement is attractive because each separate facet is a hexagon and therefore approaches the circular shape which is intuitively desirable for fabrication.

Another case in which each modular panel is made up of hexagonal tiles is the 12-tile module. The efficiency is 4 percent lower but would be tolerable if the smaller tiles would be significantly easier to fabricate. This arrangement is discussed more fully in the following pages.

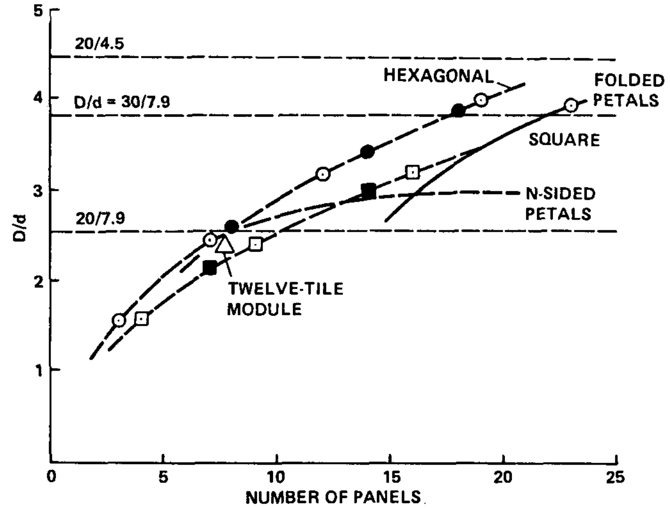
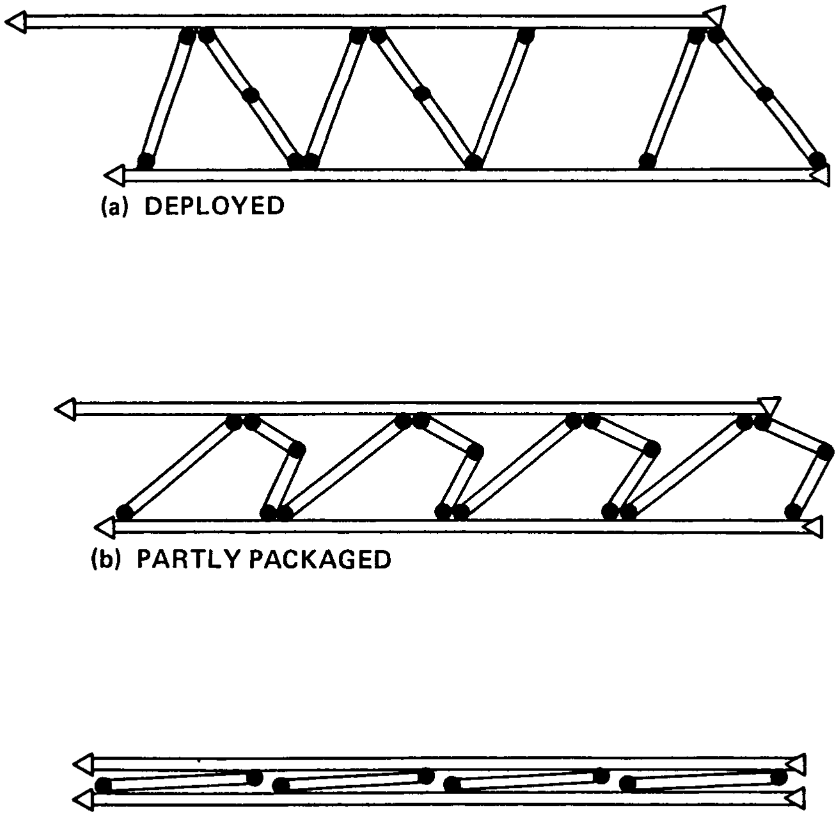


Figure 5

PACKAGING CONCEPTS

In order to reduce the thickness of the stowed modules, the deep support truss must be packaged. The approach chosen to package the tetrahedral support truss is to shear one of the surfaces against the other as is illustrated in the sketches in Figure 6. One set of intersurface members has knee joints at their centers that allow them to bend and permit the shearing motion. The other intersurface members hinge at their intersection with the surface in order to allow free shearing. Note that the hinges are indicated by the black circles and that the assembly joints to the adjacent modules are indicated by the triangles. Note also that an intersurface member is seemingly missing at the left-hand end. This absence is purposeful in that doubling up of members in the assembly is thereby avoided. Of course, if the module were an edge module, extra members would be added to close out the structure.



(a) DEPLOYED

(b) PARTLY PACKAGED

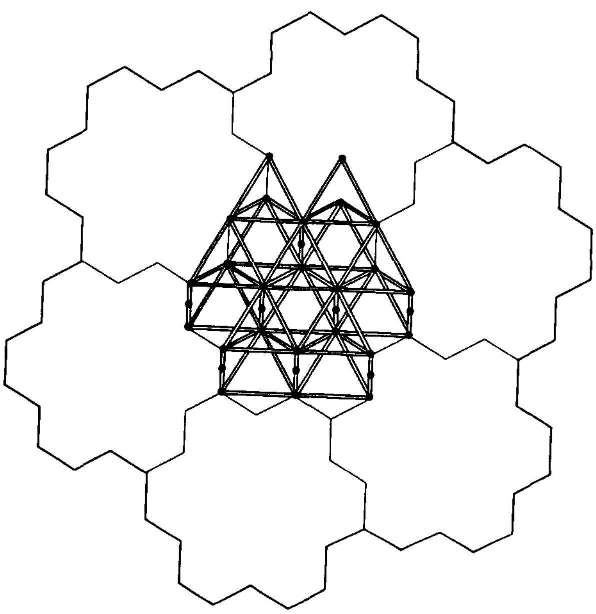
(c) PACKAGED

Figure 6

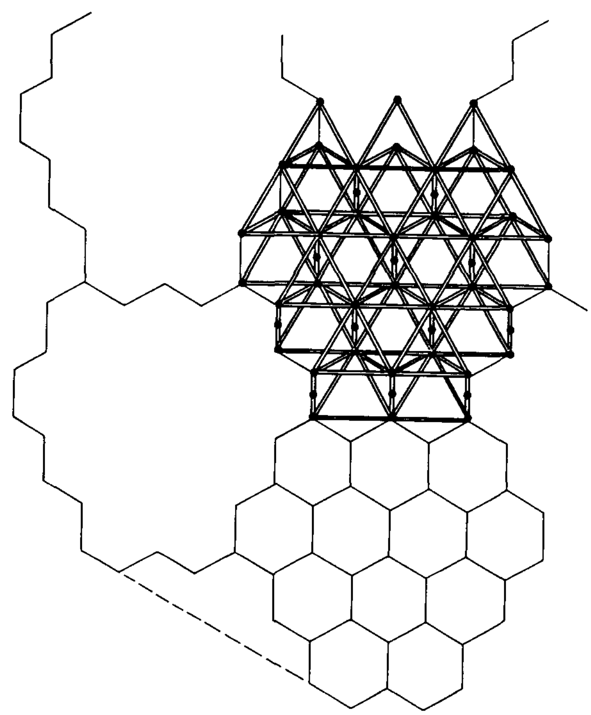
SUPPORT TRUSS GEOMETRY

The arrangement of present and missing members is shown in Figure 7a for the seven-tile module and Figure 7b for the 12-tile module. In both figures, the support truss for a module is shown as it appears when viewed looking through the truss to the rear of the reflector tiles.

Note that two choices can be made as to which of the intersurface members will act as knees. The choice shown involves a minimum of joints. The other pivoting set, however, along with the surface members, comprises a statically determinate "rib" which will package by rotation only if the truss is flat. Thus, the modules cannot be stacked together snugly. The alternative would be to put knee joints in the other set; then the pivoting set would not constitute a structure and would therefore tolerate a curved truss.



(a)



(b)

Figure 7

STOWAGE DEPTH

Since it is possible to have the packaged truss occupy the same area as do the reflector panels, the measure of packaging efficiency is the depth of the package. Assume that the reflector tiles are 0.1-m thick. Assume that the structural truss can be packaged in a 0.1-m depth (this seems reasonable for truss members about 2.5 cm in diameter). Then the total local thickness would only be 0.2 m if the modules could be efficiently nested. Thus 23 panels could be stacked in the cylindrical length of the ACC payload compartment.

As mentioned above, a significant simplification results if the truss can be made flat. The cost is greater package depth. The depth of curvature of a single module is

$$\delta = \frac{(7.9)^2}{8 \times 20}$$

$$\cong 0.4 \text{ m}$$

Therefore, the package depth with a flat truss would be 0.6 m. For a seven-module truss, the total depth would be 4.2 m, which is well within the length available in the ACC. The greater simplicity of the flat truss could therefore be used. If more modules were desired, then the factor of three improvement of the curved truss would be needed.

EXAMPLE CONSTRUCTION SCENARIO

The entire spacecraft would consist of the primary reflector, a secondary reflector, a science package, a spacecraft bus, and a thermal shield. The order of assembly might be as follows for an on-axis, seven-module design (see Figure 8).

1. Assemble central reflector module to bus (the LEASECRAFT is an example of a possible bus). The interface between the bus and the module would be three struts packaged with the central module that connects three corners of the module to three hard points on the bus.
2. Assemble the science package adapter to the central module. The adapter would be mounted to a portion of the structure prior to launch with appropriate care for thermal aspects. The portion of the structure would be assembled in flight to close out the truss.
3. Assemble the secondary mirror unit to the central module. The interface would be through six struts, packaged with the secondary reflector, joining three points on the secondary reflector with the same three corners of the central module to which the bus is attached.
4. Deploy and assemble the outer modules to the central module. Each module can carry its own thermal insulating blanket.
5. Install remaining rear insulation
6. Install thermal shield
7. Mount science modules
8. Separate from Shuttle, deploy solar array, and check out
9. Boost into operational orbit

This scenario can be varied readily for other example configurations.

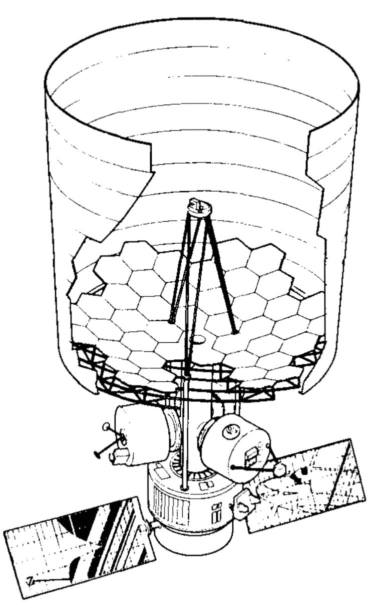


Figure 8

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